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AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Technical Note 29

DEVELOPMENT AND OPERATION OF THE F/A-18 MODEL
CONTROL SURFACE ACTUATORS

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by

S.S.W. LAM
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Technical Note 29

**DEVELOPMENT AND OPERATION OF THE F/A-18 MODEL
CONTROL SURFACE ACTUATORS**

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**S.S.W. LAM
Y.Y. LINK**

SUMMARY

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A series of test programmes in the ARL 2.7m x 2.1m Low Speed Wind Tunnel of a $\frac{1}{4}$ th scale model of the F/A-18 required the development of a software package to drive the control surfaces. This software is written in VAX FORTRAN for a MicroVAX II computer. The software communicates with the model through a specially designed Actuator Module that responds to requests from the MicroVAX II computer. In order to establish the relationship between control surface angles and Linear Variable Differential Transformer readings a cubic spline interpolation method has been implemented. This report describes the development and operation of the control surface actuators' software, and contains a detailed guide for its use.



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TABLE OF CONTENTS

1	INTRODUCTION	1
2	ACTUATOR MODULE	1
3	PROGRAM STRUCTURE	2
	3.1 Windows Set-Up.....	2
	3.2 Configuration File	3
	3.3 Cubic Spline Interpolation.....	4
4	USE OF PROGRAM ACTUATOR.....	5
	4.1 Reset Actuator Module	5
	4.2 Actuator Calibration.....	5
	4.3 Normal Operation	6
5	CONCLUSION.....	8
	ACKNOWLEDGEMENTS.....	8
	REFERENCES	9
	APPENDIX A - DATA BUS ADDRESSES FOR THE ACTUATOR MODULE.....	10
	APPENDIX B - ACTUATOR MODULE ERROR AND STATUS CODES.....	13
	APPENDIX C - CONFIGURATION FILE EXAMPLE.....	14
	FIGURES	17
	DISTRIBUTION LIST	
	DOCUMENT CONTROL DATA	

1 INTRODUCTION

A $\frac{1}{3}$ th scale model of the F/A-18 aircraft with movable control surfaces was designed and manufactured at ARL for a series of test programmes in the 2.7 m x 2.1 m Low Speed Wind Tunnel. The model is shown in the test section of the wind tunnel in figure 1. Details of the control surface mechanisms are shown in figure 2. The model control surfaces, i.e. leading edge flaps, trailing edge flaps, ailerons and stabilators, are driven by motorised actuators which are controlled remotely by an electronic module called the Actuator Module. The Actuator Module is one of several slave modules of the new data acquisition system being installed for the tunnel. These slave modules are connected to a MicroVAX II 'master' computer using a bi-directional differential parallel data bus. They are built around microprocessors to provide local intelligence to perform specific instrumentation control and data acquisition functions requested by the 'master'.

The angles of the model control surfaces are adjusted by the Actuator Module using the computer program, ACTUATOR, residing in the master computer. A stand-alone program separate from the data acquisition software on the 'master' has been developed to drive the control surfaces via the Actuator Module for the F/A-18 model tests. However, the commands for adjusting the control surfaces for any model will be incorporated into the data acquisition system software when the new data acquisition system is fully developed. This report describes the development and operation of the computer program written and resident on a DEC MicroVAX II computer, in VAX¹ FORTRAN, to control and monitor the actuators.

2 ACTUATOR MODULE

The Actuator Module was developed and manufactured at ARL (Reference [1]) and is based on a Motorola 68000 Microprocessor. It is connected to the parallel data bus via a Bi-directional Parallel Interface (BPI) card also developed at ARL. The Actuator Module has 12 channels so that 12 different control surfaces can be activated independently. A Linear Variable Differential Transformer (LVDT), close to each actuator, is connected to the control surface with a linkage system to measure the angle of the surface relative to a specified reference. The output voltage from the LVDT is passed to the Module and with an appropriate calibration gives the angle of the control surface with respect to the model fuselage reference line. The Module has a resident program that responds to requests from the master computer to perform the following functions for each channel:

- Receive the upper and lower angle setting limits for each channel.
- Return the current LVDT reading of a given actuator channel to the master computer.
- Enter the manual drive routine in which the actuator responds to move-up, move-down, pulse-up or pulse-down commands.

¹DEC, Micro VAX II and VAX are registered trademarks of Digital Equipment Corporation.

- Receive from the master computer the LVDT reading required to set a control surface to a given angle. Throughout the software this is referred to as the target LVDT reading.
- Receive the trigger command to start moving the control surface to the angle to be set.

The commands issued by the master computer to the Module are in the form of 16-bit address/vector codes whose values and functions are given in Appendix A. In addition to responding to requests from the master computer, the Actuator Module generates error and status codes to indicate the operating conditions of the actuators, and these codes are sent to the master computer on request. A list of the error and status codes is given in Appendix B.

Communication between a user program on the DEC MicroVAX II master computer and the Actuator Module through the parallel data bus is controlled by the software interface known as DIGIO. A guide to developing software that communicates with the data bus via DIGIO is given in Reference [2].

3 PROGRAM STRUCTURE

The software program to control the actuators is called ACTUATOR. It consists of 16 files as shown in figure 3. The program is designed in such a way that each file contains one or more routines that perform a unique function. The files are located in the directory DUA0:[DATAIN.BUS.ACTUATOR.LVDT] of the Low Speed Wind Tunnel MicroVAX.

The following sections contain a detailed description of ACTUATOR, the arrangement of the operator's screen, how to compile a configuration file and a description of the interpolation method used by the program to set a control surface angle.

3.1 Windows Set-up

The software utilises the VMS Screen Management routines described in Reference [4]. Nine windows are created at the start of the program to provide a 'window' environment on a non-graphics screen. Figures 4a, 4b and 4c present sample screens as seen by the user and show the screen position of the following windows:

- Menu bar window – a one line window at the top of the screen containing the commands available to the user. The highlighted character indicates the key required to be pressed to perform the operation.
- Command bar window – a one line window at the bottom of the screen containing the command prompt. When the user presses a command key the full command name will be displayed in this window. The window is also used to notify the user of certain processes that the program is currently performing.
- Main window – this window serves as the main area for communication between the program and the user.

- Data window – this window displays the LVDT readings and the corresponding angles (in degrees) they represent for each of the actuator channels used on the F/A-18 model.
- Set window – this window appears on the top half of the screen when the user enters the 'SET' command. Within this window the user sets the target angle for one or more actuators to move to.
- Manual window – this window is used for the manual drive routine in which a selected control surface may be moved up or down with simple keyboard controls.
- Help window – this window displays a brief description of each of the commands available to the user.
- F18 window – this window presents a graphical representation of the aircraft model showing the relative positions of all the control surfaces.
- Error window – this window displays messages to the user of any errors that have occurred in the Actuator Module.

3.2 Configuration File

In order to add flexibility to the software a configuration file, NEW_COEFF.DAT, is used to contain volatile data required by the program ACTUATOR. The file is read at the commencement of the program to initialise the appropriate variables. The configuration file may be edited by the user (using the standard VMS text editor) if the data contained in the file requires modification.

Data can be inserted in the configuration file to allow each control surface angle to be set and read using either a linear calibration equation or a cubic spline interpolation procedure.

An example of a configuration file is included in Appendix C and the format of the file is as follows:

1. Six lines at the top of the file for the filename and any comments.
2. Four lines made up of a blank line and three lines describing the subsequent data.
3. Seven lines each containing the value of the intercept of a linear equation relating the LVDT reading to the angle for each channel. A value of 0.0 indicates that the channel is non-functional².
4. Four lines made up of a blank line and three lines describing the subsequent data.
5. Seven lines each containing the value of the gradient of a linear equation relating the LVDT reading to the angle for each channel. A value of 0.0 indicates that the channel is non-functional.

²A description of functional and non-functional channels is given in section 4.1.

6. Four lines made up of a blank line and three lines describing the subsequent data.
7. Seven lines for the lower limit angle for each channel.
8. Four lines made up of a blank line and three lines describing the subsequent data.
9. Seven lines for the upper limit angle for each channel.
10. Four lines made up of a blank line and three lines describing the subsequent data values.
11. Seven lines for a logical value indicating the presence/absence of a valid actuator channel.
12. For each valid channel the remainder of the file contains data used by the cubic spline interpolation (refer to Section 3.3) to convert LVDT readings to angles and vice versa. The format is:
 - Four lines made up of a blank line and three lines describing the subsequent data values.
 - One line for the number of data points.
 - A blank line followed by a line containing column headings for Angle and LVDT reading.
 - For each data point the angle and LVDT reading separated by a tab spacing.

3.3 Cubic Spline Interpolation

Initially a linear equation was assumed to be sufficient to represent the relationship between the LVDT reading and the control surface angle. A calibration was performed on each control surface and a gradient and intercept calculated in order to define each linear equation. These values were input into the program via the configuration file, and the angles and LVDT readings were then calculated using these calibration values (refer to items 2-5 described in section 3.2).

Unfortunately, a linear interpolation of the calibration data was not accurate enough for the required test programme. Instead, a cubic spline interpolation method was used to carry out the conversion between LVDT reading and control surface angle. The accuracy of the conversion is better than 0.1° . However, due to the limitation in reading the templates used for the calibration and backlash in the control surface hinges, the control surfaces can only be set to within $\pm 0.5^\circ$. The cubic spline is performed within the two subroutines SPLINE and SPLINT contained in the file CUBSPL.FOR. These subroutines along with a detailed explanation of the algorithms appear in their original C format in Reference [3].

The code to perform the linear interpolation is retained in the current version of the software for the following reasons. Firstly, run-time for the linear code is faster than the cubic spline code. Secondly, depending on the design of the actuator linkages, linear

conversion between LVDT readings and angles can in some cases be as accurate as the spline method and therefore should be used where acceptable for efficiency. Finally, the linear conversion can be used to extrapolate values beyond the calibrated range, whereas the spline method is only defined within the calibrated range.

4 USE OF PROGRAM ACTUATOR

This section describes how to use the program ACTUATOR that has been written to drive the control surface actuators on the F/A-18 model. It is assumed that the operator has the required knowledge of how to login to the MicroVAX computer and is in the appropriate directory containing the program. The program must be used in conjunction with the interface program DIGIO which also has to be installed on the system (Reference [2]). The following procedure must be performed in the order stated to ensure the correct operation of the actuators and the program.

1. Reset the Actuator Module.
2. Perform actuator calibration.
3. Update the configuration file.
4. Initiate normal operation of actuators.

If the operator is confident that the current calibration is still valid then steps 2 and 3 above may be deleted.

4.1 Reset Actuator Module

The Actuator Module resets itself when the power is turned on. A built-in program within the Module initialises each actuator channel by attempting to drive the actuator motor. If the corresponding LVDT reading changes more than a set number of counts from its initial value, the channel is labelled as functional. Only actuators on functional channels may be driven by the MOVE command under the SET routine (refer to Section 4.3). Actuators of a non-functional channel might be driven, however, by the MANUAL DRIVE routine if a motor exists for the actuator and there is no other defect in the system. The Actuator Module may also be reset, without the power being switched off and then on, by pressing the reset button at the rear of the Module.

It is **important** to exit the program ACTUATOR before resetting the Actuator Module and to restart the program approximately 20 seconds after the reset commenced. If the user does not exit the program, LVDT readings will continue to be read from the bus and this may cause output conversion errors in displaying these meaningless readings.

4.2 Actuator Calibration

To convert the LVDT reading to the correct control surface angle, each actuator must be calibrated using the following procedure:

1. Decide on the range of control surface angles required and choose a set of calibration angles between the upper and lower limits, including the upper and lower limits.

2. Start the ACTUATOR program and enter the manual drive mode (refer to Section 4.3 for a description of the manual drive mode operation).
3. Using the appropriate templates set the control surface to the desired angle by driving the actuator motors with the up-arrow or down-arrow key. Use the pulse mode command for finer control surface movement.
4. Record the angle and the LVDT reading.
5. Repeat steps 3 and 4 until all the desired angles are recorded.

The angles and their respective LVDT readings must then be entered into the configuration file NEW_COEFF.DAT using a text editor (refer to Section 3.2 for a more detailed description of the configuration file).

4.3 Normal Operation

At the VMS prompt type:

```
run actuator
```

The screen will clear and the actuator program main window will appear. A message informing the user that the configuration file is being loaded will appear at the bottom of the screen. Any error/status message reported by the Actuator Module will be displayed at the start of the program.

The allowable commands in the main menu of ACTUATOR, which appear along the top line of the screen in the menu bar window, are presented in Table 1 and a detailed description of each command follows the table.

Key	Command	Description
H	Help	Displays a list of allowable commands
S	Set	Enter set angle routine
L	Lower limit	Display lower limits
U	Upper limit	Display upper limits
O	Offset	Display offsets
F	Load Coefficients	Download calibration coefficients
C	Clear	Clear window
D	Manual Drive	Enter manual drive routine
E	Exit	Exit the program

Table 1: List of Commands in Program Actuator Main Menu

Help – This command displays a window similar to Table 1, listing the commands that are available to the user.

Set – With this command the user enters the command window for normal operation of the actuators. The set window displays the target angles to which each control surface is to be moved. A highlight bar indicates the selection of a control surface whose target angle may be altered. In order to change the target angle, simply enter the new value from the keyboard. Use the backspace key to delete mistyped characters. A different control surface is selected by pressing the right-arrow or left-arrow key. A diagrammatic representation of the aircraft in the middle of the screen presents a graphical indication of the currently selected control surface.

When the user has finished setting all the target angles, pressing the 'M' key (MOVE command) will start the actuator motors, moving the control surfaces to their respective target angles. The moving actuators are shown on the diagrammatic representation of the aircraft by a flashing surface. On completion of the move a bell will sound and the surfaces on the screen will cease flashing.

Lower/Upper Limit – These commands display a window containing the lower/upper limits of each of the actuators.

The Actuator Module only recognises LVDT values and the conversion of an angle to an LVDT value is performed within the program ACTUATOR. An LVDT attached to a control surface returns a voltage between 0 and +10 volts and this is converted to an integer number between 0 and 2047. The lower and upper limits are defined by the LVDT readings, i.e. a lower limit may be $+11^\circ$ and an upper limit may be -26° because the LVDT readings are 350 and 970 respectively (this method for defining the upper and lower limit of an actuator is due to the physical set-up of the LVDT). The user sets these limits, in degrees, through the configuration file and the program ensures, through software limits, that the target LVDT value is within the allowable range.

Offset – This command displays a window with the offsets. These values are not defined in this version of the software, and should be disregarded by the user.

Load Coefficients – This command reads in the calibration coefficients from the configuration file NEW_COEFF.DAT. This occurs at the start of the program, but it can be performed at any stage within the program if it is necessary.

Clear – This command is used to clear the main window of any messages that are not needed anymore.

Manual Drive – This command allows the user to drive the actuators to any position permitted by the hardware configuration, overriding the LVDT limits set by the user in the configuration file. The user moves the actuators with the up-arrow and down-arrow keys, and stops the move with the space bar. Two modes for controlling the actuators are available. They are:

- pulse mode off – a coarse mode in which an actuator motor starts in response to either the up-arrow or down-arrow key and continues to move until the space bar is pressed.
- pulse mode on – this mode provides the user with fine control of the actuator's motion. A short pulse of electrical current is sent to the actuator motor each time the up-arrow or down-arrow key is pressed, so that the actuator is moved through only a short displacement.

Initially the user is in 'pulse mode off' and the user switches to 'pulse mode on' by typing 'P'. The user may switch between these two pulse modes as many times as necessary by typing 'P'. The user exits manual drive mode by typing 'E'.

The manual drive mode must be used with extreme caution because no software or hardware limits are present while the operator is driving the actuators from this menu option.

Exit – Pressing the 'E' key indicates that the user wishes to exit the program. Confirmation is requested by the program and the user types 'Y' to confirm the exit.

5 CONCLUSION

The software program ACTUATOR provides the user with full control of the control surface actuators on the F/A-18 model from a terminal connected to the Low Speed Wind Tunnel MicroVAX II. Although the program was developed as a stand-alone module, it is intended to incorporate it in the wind tunnel data acquisition system software as development proceeds. The development and operation of the software program ACTUATOR has been described in this report.

ACKNOWLEDGEMENTS

The authors would like to thank Mr Steven Kent for his support in the development of the actuator control system, and the wind tunnel operators for their advice concerning the use of the software as it was being developed.

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2. Fairlie, B.D., and Lam, S.S.W. *A Software Interface For The ARL Wind Tunnel Data Acquisition System*. Department of Defence, Defence Science and Technology Organisation, Aeronautical Research Laboratory, Technical Report, ARL-TR-14, March 1993.
3. Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T. *Numerical Recipes in C - the art of scientific computing*. Cambridge University Press, Cambridge, 1988.
4. *MicroVMS Programming Support Manual*. Order number AI-DC87B-TE. Digital Equipment Corporation, Massachusetts USA, April 1986.

APPENDIX A - DATA BUS ADDRESSES FOR THE ACTUATOR MODULE

Address	Description
8B60	string1 - error code
8B61	unused
8B62	string2 - module identification
8B63	master trigger
8B64	string3 - unused
8B65	clear status/error buffers
8B66	string4 - unused
8B67	clear error and flag bits
8B68	string5 - unused
8B69	trigger actuator movement
8B6A	string6 - unused
8B6B	unused
8B6C	string7 - unused
8B6D	unused
8B6E	string8 - unused
8B6F	unused
8B70	Ch. 1 LVDT reading to master
8B71	Ch. 1 target LVDT from master
8B72	unused
8B73	Ch. 1 upper limit from master
8B74	Ch. 1 upper limit to master
8B75	Ch. 1 lower limit from master
8B76	Ch. 1 lower limit to master
8B78	Ch. 2 LVDT reading to master
8B79	Ch. 2 target LVDT from master
8B7A	unused
8B7B	Ch. 2 upper limit from master
8B7C	Ch. 2 upper limit to master
8B7D	Ch. 2 lower limit from master
8B7E	Ch. 2 lower limit to master
8B80	Ch. 3 LVDT reading to master
8B81	Ch. 3 target LVDT from master
8B82	unused
8B83	Ch. 3 upper limit from master
8B84	Ch. 3 upper limit to master
8B85	Ch. 3 lower limit from master
8B86	Ch. 3 lower limit to master
8B88	Ch. 4 LVDT reading to master
8B89	Ch. 4 target LVDT from master
8B8A	unused

Address	Description
8B8B	Ch. 4 upper limit from master
8B8C	Ch. 4 upper limit to master
8B8D	Ch. 4 lower limit from master
8B8E	Ch. 4 lower limit to master
8B90	Ch. 5 LVDT reading to master
8B91	Ch. 5 target LVDT from master
8B92	unused
8B93	Ch. 5 upper limit from master
8B94	Ch. 5 upper limit to master
8B95	Ch. 5 lower limit from master
8B96	Ch. 5 lower limit to master
8B98	Ch. 6 LVDT reading to master
8B99	Ch. 6 target LVDT from master
8B9A	unused
8B9B	Ch. 6 upper limit from master
8B9C	Ch. 6 upper limit to master
8B9D	Ch. 6 lower limit from master
8B9E	Ch. 6 lower limit to master
8BA0	Ch. 7 LVDT reading to master
8BA1	Ch. 7 target LVDT from master
8BA2	unused
8BA3	Ch. 7 upper limit from master
8BA4	Ch. 7 upper limit to master
8BA5	Ch. 7 lower limit from master
8BA6	Ch. 7 lower limit to master
8BA8	Ch. 8 LVDT reading to master
8BA9	Ch. 8 target LVDT from master
8BAA	unused
8BAB	Ch. 8 upper limit from master
8BAC	Ch. 8 upper limit to master
8BAD	Ch. 8 lower limit from master
8BAE	Ch. 8 lower limit to master
8BB0	Ch. 9 LVDT reading to master
8BB1	Ch. 9 target LVDT from master
8BB2	unused
8BB3	Ch. 9 upper limit from master
8BB4	Ch. 9 upper limit to master
8BB5	Ch. 9 lower limit from master
8BB6	Ch. 9 lower limit to master

Address	Description
8BB8	Ch. 10 LVDT reading to master
8BB9	Ch. 10 target LVDT from master
8BBA	unused
8BBB	Ch. 10 upper limit from master
8BBC	Ch. 10 upper limit to master
8BBD	Ch. 10 lower limit from master
8BBE	Ch. 10 lower limit to master
8BC0	Ch. 11 LVDT reading to master
8BC1	Ch. 11 target LVDT from master
8BC2	unused
8BC3	Ch. 11 upper limit from master
8BC4	Ch. 11 upper limit to master
8BC5	Ch. 11 lower limit from master
8BC6	Ch. 11 lower limit to master
8BC8	Ch. 12 LVDT reading to master
8BC9	Ch. 12 target LVDT from master
8BCA	unused
8BCB	Ch. 12 upper limit from master
8BCC	Ch. 12 upper limit to master
8BCD	Ch. 12 lower limit from master
8BCE	Ch. 12 lower limit to master
8BD0	motor status register
8BD1	enter motor manual test mode
8BD2	unused
8BD3	direction for motor to move
8BD4	unused
8BD5	exit motor manual test mode
8BD6	unused
8BD7	lvdt read only channel vector
8BD8	unused
8BD9	motor power relay control
8BDA	unused
8BDB	turn manual pulse mode on
8BDC	unused
8BDD	turn manual pulse mode off

APPENDIX B - ACTUATOR MODULE ERROR AND STATUS CODES

Error Code	Description
EAx0	actuator not functioning
EAx1	master set upper limit reached
EAx2	master set lower limit reached
EAx3	upper limit not specified
EAx4	lower limit not specified
EAx5	time-out expired, actuator stalled
EAF0	emergency stop switch has been disabled
EAF1	motor power safety relay has been disabled
E000	all actuator motors are stationary

The 'x' is substituted by the actuator channel number to which the error refers.

APPENDIX C - CONFIGURATION FILE EXAMPLE

File: NEW_COEFF.DAT

This file contains the 7 actuator coefficients (slopes and intercepts) and upper/lower limits. These values are initialised each time ACTUATOR is run.

LVDT vs. Actuator Angle Intercept

Channel 1 = 1245.32
Channel 2 = 854.5357
Channel 3 = 360.4
Channel 4 = 710.6
Channel 5 = 0.0
Channel 6 = 0.0
Channel 7 = 1603.3867

LVDT vs. Actuator Angle Gradient

Channel 1 = -26.7238
Channel 2 = -25.478
Channel 3 = 20.92
Channel 4 = 16.22
Channel 5 = 0.0
Channel 6 = 0.0
Channel 7 = -32.3316

Lower Limits (angle)

Channel 1 = 11.00
Channel 2 = 11.00
Channel 3 = -1.00
Channel 4 = -1.00
Channel 5 = -11.00
Channel 6 = 11.00
Channel 7 = 35.00

Upper Limits (angle)

Channel 1 = -26.00
Channel 2 = -26.00
Channel 3 = 21.00

Channel 4 = 21.00
Channel 5 = 11.00
Channel 6 = -11.00
Channel 7 = -1.00

Valid Channels

T

T

T

T

F

F

T

Channel 1 - Calibration Points

10 No. Data Points

Angle LVDT

-26.0 1908.0

-25.0 1878.0

-20.0 1756.0

-15.0 1633.0

-10.0 1502.0

-5.0 1366.0

0.0 1231.0

5.0 1092.0

10.0 958.0

11.0 933.0

Channel 2 - Calibration Points

10 No. Data Points

Angle LVDT

-26.0 1544.0

-25.0 1498.0

-20.0 1380.0

-15.0 1261.0

-10.0 1136.0

-5.0 1007.0

0.0 886.0

5.0 754.0

10.0 607.0

11.0 594.0

Channel 3 - Calibration Points

7 No. Data Points

Angle LVDT

-1.0 300.0

0.0 324.0

5.0 489.0

10.0 581.0

15.0 674.0

20.0 767.0

21.0 783.0

Channel 4 - Calibration Points

7 No. Data Points

Angle LVDT

-1.0 689.0

0.0 706.0

5.0 792.0

10.0 882.0

15.0 953.0

20.0 1031.0

21.0 1047.0

Channel 7 - Calibration Points

10 No. Data Points

Angle LVDT

-1.0 1636.0

0.0 1603.0

5.0 1447.0

10.0 1284.0

15.0 1111.0

20.0 953.0

25.0 785.0

30.0 646.0

34.0 504.0

35.0 472.0

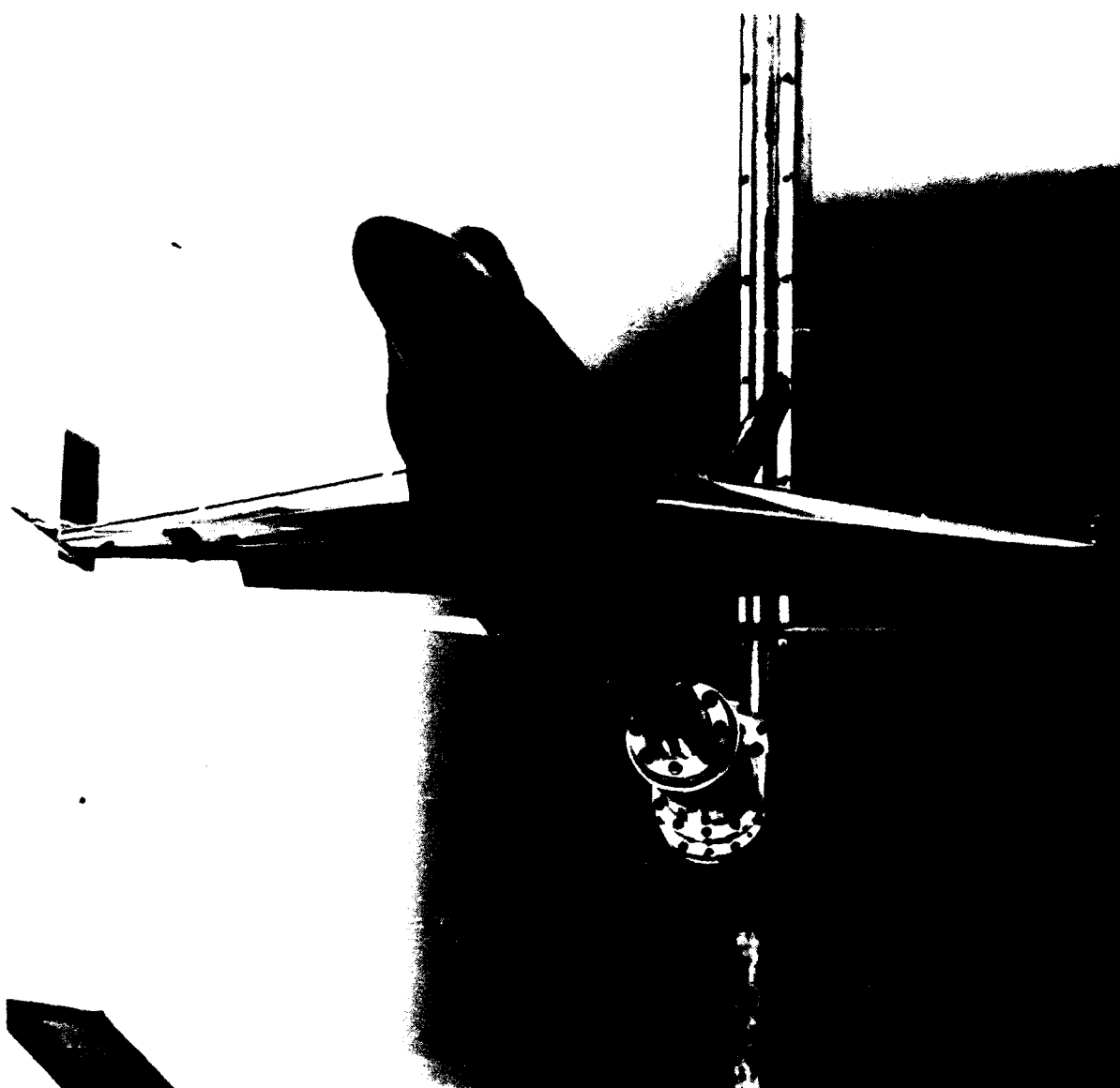


Figure 1. F/A-18 Model Mounted in the Low Speed Wind Tunnel

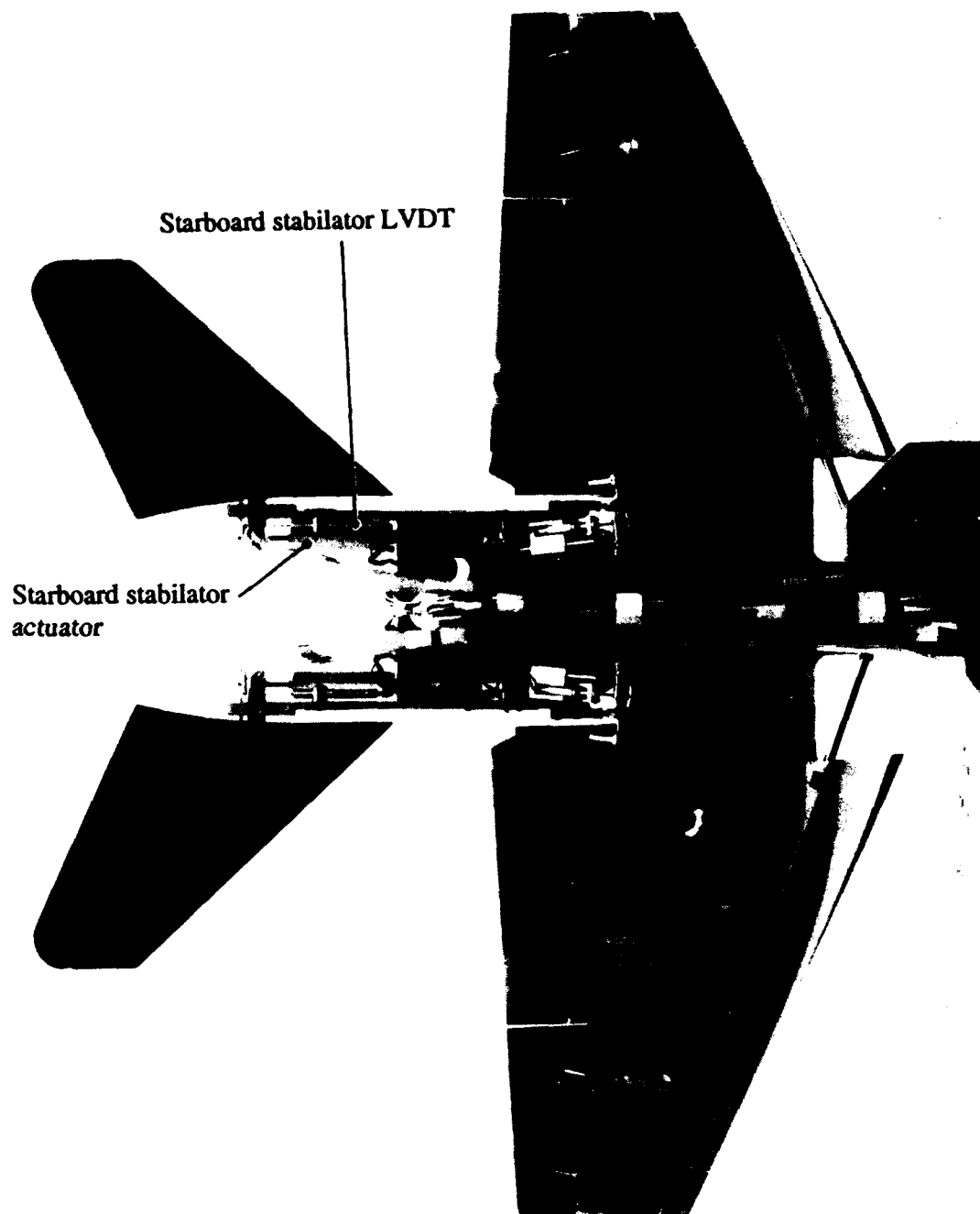


Figure 2. F/A-18 Model Showing Actuators and LVDTs

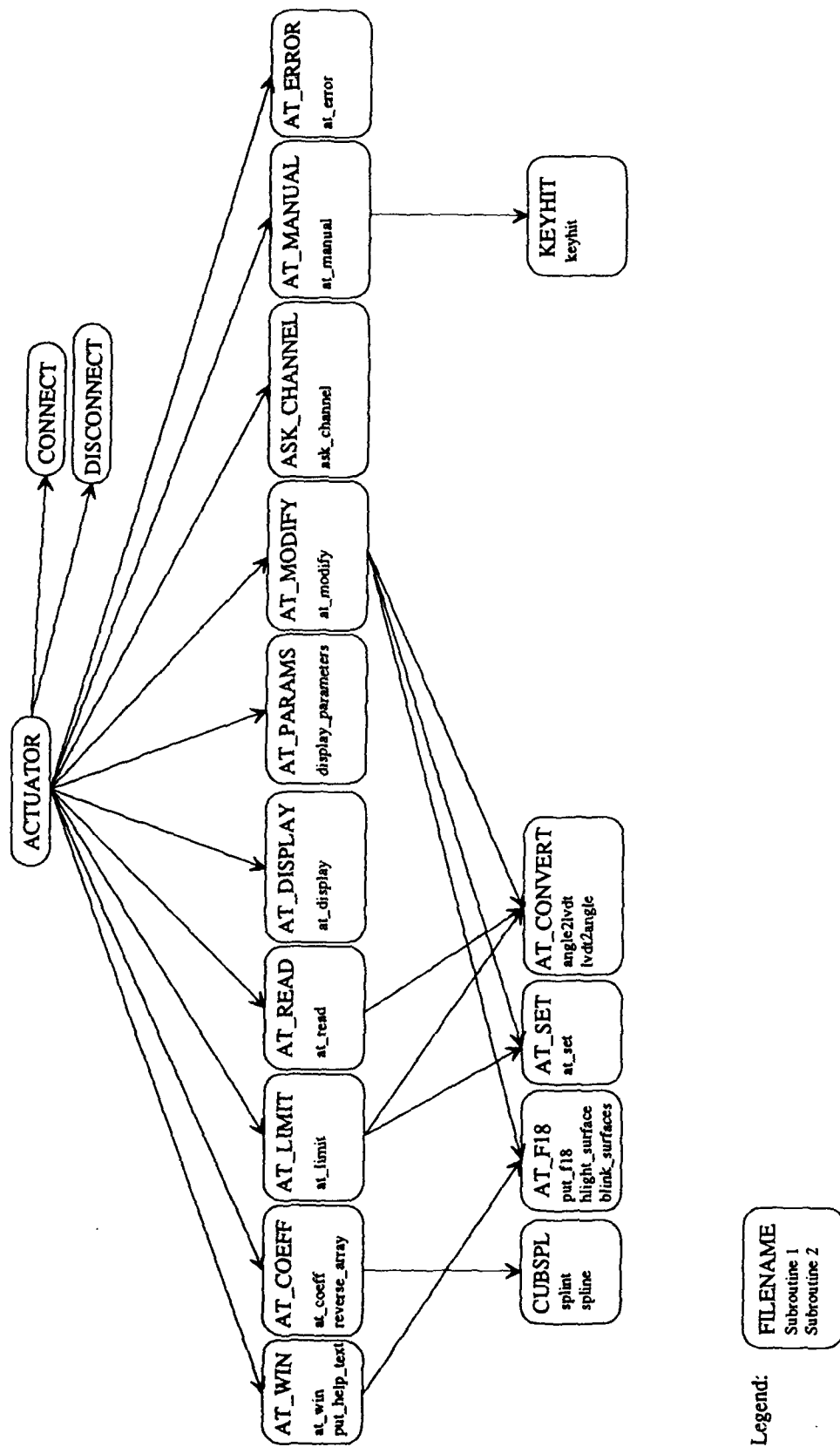


Figure 3. Overview of Program Structure

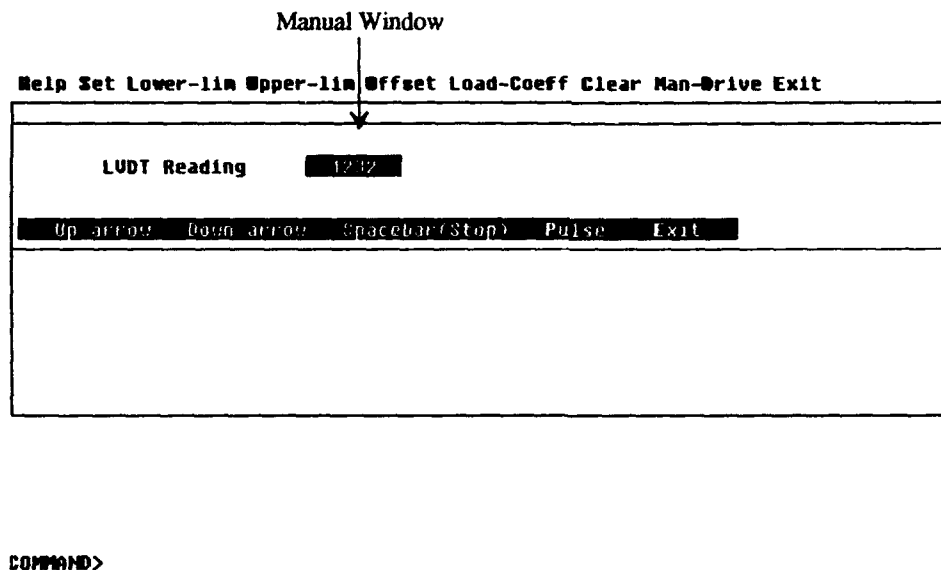
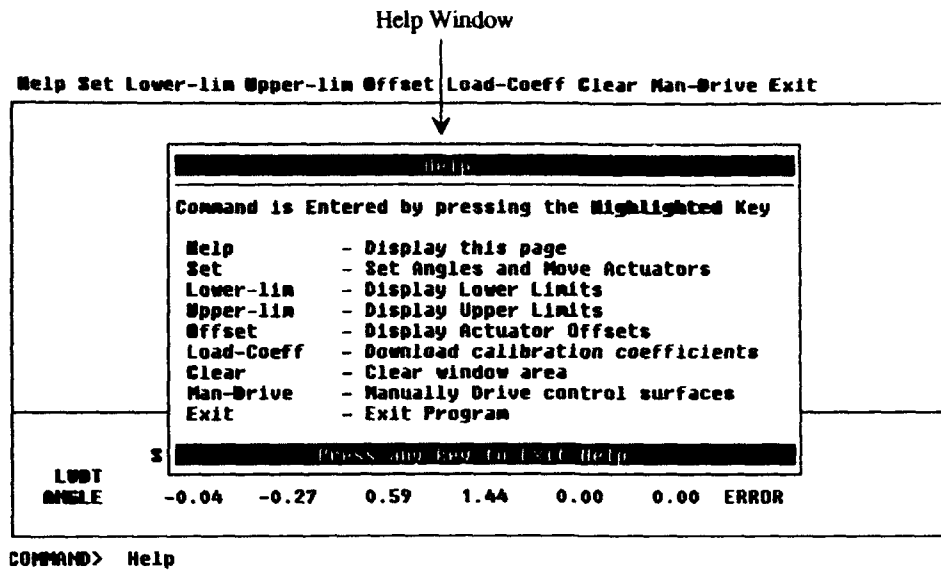


Figure 4b. Help screen and Manual drive screen

Display Lower Limits							
S Stab	P Stab	S TEF	P TEF	S All	P All	LEF	
11.00	11.00	-1.00	-1.00	-11.00	11.00	35.00	
Hit any key to continue							

COMMAND> Display Lower Limits

Error Window

Help Set Lower-lim Upper-lim Offset Load-Coeff Clear Man-Drive Exit

<p>*** Error from module 88 *** Actuator 7: Not Functioning</p> <p>*** Error from module 88 *** Actuator 8: Not Functioning</p> <p>*** Error from module 88 *** Actuator 9: Not Functioning</p> <p>*** Error from module 88 *** Actuator 10: Not Functioning</p> <p>*** Error from module 88 *** Actuator 11: Not Functioning</p> <p>*** Error from module 88 *** Actuator 12: Not Functioning</p> <p>*** Error from module 88 *** Actuator 7: Not Functioning</p> <p>*** Error from module 88 *** Actuator 5: Not Functioning</p> <p>*** Error from module 88 *** Actuator 6: Not Functioning</p> <p>*** Error from module 88 *** Actuator 7: Not Functioning</p>							
LUDT	S Stab	P Stab	S TEF	P TEF	S All	P All	LEF
ANGLE	1228	891	368	737	0	0	2
	0.11	-0.23	1.91	2.21	0.00	0.00	ERROR

COMMAND> Press Any Key To Continue...

Figure 4c. Limits screen and Error screen

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